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Andreas Dracopoulos and Ergoliptiki, and the Introduction of Reinforced Concrete in Greece

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Introduction

Current research in the history of modern concrete focuses on material composition, the patented systems and associated business, as also the origins of systems like precast and prestressing, while thin shells is always a popular area. Reviewing the recent International Construction History conferences for example, deeper research can be found on major (Hennebique, Coignet, Nervi) or lesser known figures, the emergence of scientific and experimental methods, but also regional developments outside mainstream countries (Brazil, Venezuela, Taiwan, Russia).

It is worth investigating Greece in this context in the beginning of the twentieth century, as a country getting slowly industrialised and urbanised, with concrete supporting the associated infrastructure. Little has been written of the technical advancements of the period in Greece and this can be expanded with research on the main figures. Ergoliptiki was one of the first major contractors in Greece, specialising in reinforced concrete (RC) and working on a wide range of public infrastructure projects, but equally as important, on many private buildings as well, of various scale and use. Their archive was recently salvaged and purchased by the collector G. Lambrou, and a monograph was subsequently published by the heritage organisation MONUMENTA focusing on their technical director, Andreas Dracopoulos, sponsored by his grandson with the same name [1]. This paper extends that monograph with technical analysis of Dracopoulos' work, especially some representative buildings in the period he was working there (1918-45), framed within the practice of its time.

There are some particular conditions of the Greek applications that may interest the broader context of early RC studies: earthquakes (as a major load to be considered in design), scale and the eclectic style of buildings of the period, especially due to demand for office buildings in the centre of Athens; technical achievements of a new building trade that apparently relied little on external input from approved Hennebique instructors as in other countries (UK); the permutations of a construction system that was based on Hennebique's rules till 1950 when the first Greek concrete regulations were published.

This work aims to understand the particular technology used by Ergoliptiki in their early concrete buildings in the Greek context, framing them in the UK and Italian contexts, which have been more deeply studied and had concrete regulations from the first 20 years of the century. The major early concrete frames Ergoliptiki built in Athens in the 1920s will be discussed, which were behind some very large scale buildings for the period but still in eclectic styles that do not reveal the tectonics of the material (mainly because they were created before the advent of Modernism). As there is little in general on the introduction of reinforced concrete in Greece, a reflection will be made on further stages for research.

The introduction of reinforced concrete in Greece

The first stages of the establishment of reinforced concrete in Greece are usually discussed as an innovative approach in some large scale and eclectic buildings in Athens in the 1910s and 1920s, but with little critical technical overview [2][3][4]: Megaro Afentouli (1907) [5], Megaro Palli (1910-11) [6], Megaro Giannarou in Syntagma (1917-21) and Megaro Efesiou (1923-28), all in Athens. Also, there is almost no original study of the first applications of concrete, like what system was followed and with what variations, what sizes and spans were achieved, what was the composition of the concrete mix, who were the first contractors (and their experience), etc.

It is largely viewed that contemporary trends from Europe were followed conservatively. In particular, the Hennebique system, as the monolithic construction of beams and columns was appreciated as suitable for seismic areas like Greece, and some of the designers were acting as its local agents. As with other countries, the structural focus was on sheer strength, provide tensile strength and make the most of monolithic construction. Names of engineers and contractors specialising in concrete in the period are very little known, in contrast to the architectural designers [7] for who, on the other side, is rarely clear how responsible they were for the choice and application of concrete. This lack of a technical or architectural context is compensated in this work by referring to other European countries to frame the argument.

The importance of the Hennebique system for the development of RC in Europe is well known, while other developments like prestressing came much later. For example, the first prestressed bridge in Germany, the Oelde Autobahn Bridge, was built under a Freyssinet licence in 1938 [8].

Significant applications are found in all Europe, such as with Spain's innovation. [9]. Extensive scientific research took place in Germany, UK, USA and France during the inter-war period on material properties, cement substitutes, strength of various types of reinforcement and their bonding, durability, strength of members under the main force types (shear, buckling), etc [10].

Italy had regulations established as early in the twentieth century and Dora Foti provides an extensive critical review of the key stages, main points and prescribed strength [11]. The first regulation, the 1907 Royal Decree-Law recognised the lack of the tensile and shear strengths of the conglomerate, entrusting them at the re-bars, which are further prescribed an axial tensile or compressive stress of min 100 MPa (N/mm²). Progressively, the material strength safety factor would be refined (DP 15/5/1925) and concrete strength when reinforced in shear would be defined (1.4 MPa in RDL 18/7/1930), towards the more complex RDL 16/11/1939 n. 2229, which moves away from prescriptive into performance criteria and refines safety factors, concrete mix design and shear reinforcement.

Another interesting aspect of the period is the use of concrete as a restoration material until at least 1945 [12]. Concrete appeared as the ideal modern conservation material in a period when conservation was seen as a purely technical problem (*Restauro Scientifico* as advocated by Camillo Boito, Gustavo Giovannoni): it avoids falsification, provides reliable structural strength and stiffness which assist a more quantifiable analysis. N. Balanos also followed this practice in Greece during his controversial restorations in the Athenian Acropolis in 1899-1902 and 1922-33.

In the UK, regulations arrived later in the 1920s, often viewed as a reaction to the monopoly established by Hennebique and his agent Mouchel [13][14]. A comprehensive review of the sector in the UK, with regards to procurement, material development and the range of applications was outlined by the Institution of Civil Engineers [15] and a similar review was attempted more particularly for Scotland [16], and these studies can be framed in the broader technical context for all major material systems sketched by J. Sutherland [17]. These studies show that specialists who were licensed to design according to a system, had to be appointed by architects or the client and they had to work with a trusted contractor to guarantee material quality and workmanship. However, in an effort to standardise strength appraisal among all the systems, the RIBA Joint Committee Report was prepared in 1907. Concrete at that period had also low compressive strength of 15-20 MPa and the compaction of the conglomerate was done by hand till 1900, requiring a higher water-cement ratio for workability, which would lower the strength. A system that became popular, especially for houses was “no-fines” concrete, containing almost no sand. Local codes (London – LLC) would appear from 1916 until the first national code in 1945.

As Greece is a seismic area, it is interesting to draw parallels with the better documented technology the Italians applied in the Dodecanese when the islands were under their administration (1922-1946) [18]. The architects employed there wanted to experiment with modernist developments in the technical field and RC appeared as a technical solution against earthquake risk. Italian engineers of the period were developing significant experience in the seismic design of buildings especially after the catastrophic earthquake of Messina and Reggio Calabria in 1908, which pushed for the development of the first major Italian seismic regulations in 1909 (Regio Decreto no. 193 del Aprile 18, 1909), which were tested in the earthquakes of Sora and Avezzano in 1915. These codes prohibited structural elements that applied thrusts and limited spacing of load-bearing elements to 5m; improved connections of the structural parts; and promoted the design of structural skeletons (in timber or concrete), phasing out load-bearing masonry, though they realized its contribution to the seismic performance of buildings and chose to retain it as a “secondary” system (infill walls). The following characteristics are recorded:

- RC structural systems, i.e. columns, beams and solid or ribbed slabs, using masonry units as fillers.
- Load-bearing elements primarily in masonry, in combination with RC columns and solid or ribbed slabs, using masonry units as fillers.
- Poor quality of materials: unwashed sea sand and sea gravel in the concrete mix; non-standardized mild steel; uncontrolled aggregate classification and grading.
- Moderate scale construction technology: small sections for the longitudinal steel reinforcement bars in columns/beams; long distances of stirrups in beams/columns, with small section.

The vertical concrete elements vary in size depending on the masonry walls dimensions, with typical widths of 20-30 cm. The location of these elements indicates that the engineers sought typical beam spans aiming to a well-defined “grid”.

Regulations in Greece were established in 1954 [19] and appeared as quite detailed, probably following a long scientific and practical experience over the previous 30 years. Brief mention to relevant points will be made here as earlier practice may be indicated, referring possibly to Ergoliptiki as well. Relatively low strengths, compared to modern measures, were specified like C12 for standard constructions (referred to as B 120) and C22 and C30

for special constructions. Mechanical vibrators were recommended for compacting the mix. Loading tests on the finished structure are permitted and regulated (art. 37) but with caution and only when necessary. The cover recommended was 10 mm at least. References are often made to spandrel beams (as per Hennebique system) or even T-beams bonded into the slab, while slabs are given a minimum thickness of 7 cm (art. 54).

In terms of design applications, RC frames would become a prominent element in Greek architecture primarily with the advent of Modernism in the country. The extensive and innovative school building programme of the 1930s, characterised by the designs of Patroklos Karandinos, often raised the debate whether frames had to be designed by the engineers of the period or it was material system with rules that could be understood by architects [20]. The IV CIAM took place in Athens in 1933 and among the Greek speakers, P. Santorinis spoke of contemporary RC advancements (and benefits like monolithic, jointless construction) and the advent of scientific sizing through calculations, making reference to the mushroom columns he had designed for the Kronos factory in Eleusis earlier in 1923. [21] As an academic, he was aware of advancements elsewhere and he was also experimenting. The phenomenon of polykatoikia (the ubiquitous blocks of flats in urban Greece) had started already establishing from the late 1920s and one of the most famous examples is the Blue Polykatoikia, in Exarcheia at central Athens in 1932.

Returning to the more technical drivers of RC systems in buildings, the civil engineer Ilias Aggelopoulos (1859-1932), educated in France, is considered as the pioneer of the introduction of RC in Greece at Afentoulis Mansion in Athens (1907) [22] [23]. He had already designed two replacement RC bridges over the Kifisos River in Athens, built by the Agapitos company, who would later develop into Ergoliptiki [24].

Parallel developments would happen in the manufacturing sector. Another engineer, Zachariou would found the Titan cement company in 1899 and their major factory in Eleusis from 1910 is still the biggest in Greece - another major cement company, AGET would be founded in 1911 in Drapetsona [25]. Zachariou founded also Tekton, specialised in RC construction, who delivered several major buildings like banks, industrial buildings (like flower mills in Piraeus 1910, water towers, barrel vault roofs).

Ergoliptiki

The company evolved from the earlier contractor Agapitos when bought and expanded by Moschos Diamantopoulos. Ergoliptiki would also appear as agents of the Hennebique system, very important through their business life as the first RC regulations in Greece would be established only later in 1954. They were the contractor of the projects, building up their expertise which apparently made them not require the importation of specialist contractors, as was the practice abroad. Thus, the material system soon became embedded in Greek building practice.

Andreas Dracopoulos (1890-1971) was their technical director from 1918 to 1945 and a board member, thus having a key role in the delivery of several significant projects of the period. He graduated as a civil engineer from the National Technical University of Athens and then did his national service as an army engineer, gaining valuable experience in the design of barracks.

Ergoliptiki's concrete frames in the 1920s are often very robust and still dictated by the eclectic architectural design scheme (see Papaleonardou Residences (1925) or the Majestic Hotel in Athens later), showing that concrete technology was moving slowly from masonry prototypes in smaller buildings. The study of many of

Dracopoulos' projects below shows that slab sizes would often be small, but the RC skeleton would be trusted for the large spans of lobbies or shops and was fundamental for multi-storey construction. It is interesting to note these structures seldom followed modernist architectural designs even after the 1930s, which would have clearly exhibited the merits of the system, but mostly historicist patterns that give the impression of masonry construction.

A broad study of the documentation salvaged for many of Dracopoulos' buildings shows some of their technical aspects [26]. Simple structural schemes with a regular grid were followed, with not very large spans (4-5 m). There is no evident emphasis on stiffness with the presence of shear walls or cores, but there are mostly robust columns and slabs, laid on deep strip foundations. A range of primary and secondary columns is observed, the latter probably necessary to carry the heavy masonry cladding of the buildings.

Figure 1 shows concreting in a building, probably early compacting of a slab by hand trowels, before the advent of mechanical compaction. It is interesting to reflect on what those masons were probably thinking of the brand new construction system they were using, this mesh of steel reinforcement to be bonded with a fluid material, all so different from the rubble stonework or brickwork of the earlier surrounding buildings. Their earlier buildings would have their skeleton bonded with ashlar load-bearing masonry as the envelope.



Figure 1. Hand finishing of a slab casting at an unidentified site [27]

The company would be involved in major buildings in Athens, like the Laikí Trapeza (designed by An. Metaxas in 1925), Hotel Cecil (1922-24) or the extension of the M. Brettania hotel, and often they would work closely enough with architects like An. Metaxas (the author of the early Megaro Palli in 1911).

Concrete frames in eclectic major buildings in Athens in the 1920s



Figure 2. Majestic Hotel (1915) showing robustness of members and eclectic design [28]

The Majestic Hotel at the centre of Athens started as the Georgios Ventouris Mansion and was designed by architect I. Ydraios, on a not very large site, 17 x 16m, but on a prominent location. Drawings show that larger spans were required for a lobby at ground floor, with much less internal columns than in the upper floors (Fig. 3), but overall the average spans are small, around 3 m. It is probably the scale of the building which required a RC skeleton, as the structure had to be simple and robust, to allow more space for the hotel rooms. The connections of the resulting deep beams with the columns are done through a typical Hennebique chamfer. Columns reduce in section at the upper levels, which have closely spaced partitions.

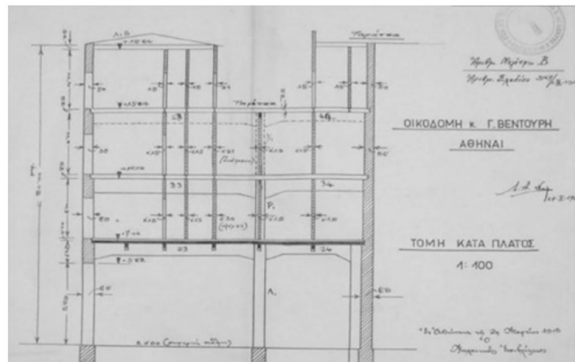
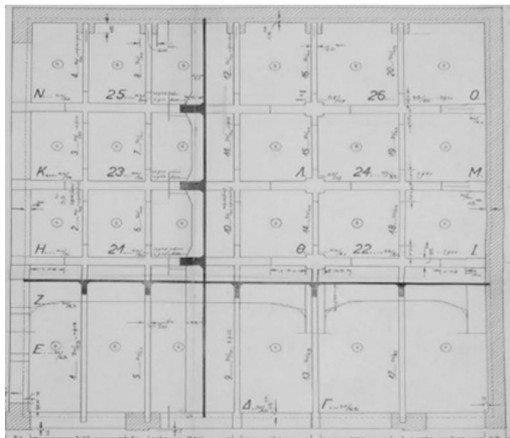


Figure 3. Majestic Hotel: a) typical floor plan and b) cross section [29]

Figure 2 shows how windows are still small, not trusting fully the robustness of the skeleton as the infill masonry appears to provide substantial stiffness. The change in the layout of columns from the first floor seems to be accommodated well by the deep beam with spandrels (Fig 3). The surviving documentation sheds light to the foundations system (Fig 4): a series of regular, wide strip foundations, using huge buttresses to probably contain the soil from the lateral sites, all probably still hand-compacted. The hotel construction can be compared with the larger yet simpler and more monolithic construction applied later at the Hotel Cecil in Kifissia (1922-24), where the openings are larger but still clad in masonry. The lobby has a very long, spandrel beam, with secondary beams for floors, much thinner. Each bay is clearly defined by beams, and the origins of the non-flat slab construction that is popular in Greece can be seen there.



Figure 4. Strip Foundations, Majestic Hotel [30]

Mpitzanis Mansion, was finished by Ergoliptiki in 1923-24, possibly implanting a complete RC skeleton to the first phase of the building (1914) [31]. The need for a big shopping lobby at ground level required the deep spandrel beams of the Hennebique system (typical solution in their Athenian buildings), achieving 10 m spans, probably a sign of confidence with the system by this time. Differentiation of member sizes can be seen in upper floors too, with a middle row having bigger column section and deeper spandrel beams, like a spine. Balconies appear also in RC, fully supported by the slab through secondary beams, the possible reason for a spine beam to increase the stiffness of the support and their bracing.

The drawings for Karapanou Mansion (1915-18, now demolished) [32] show in more detail how steel reinforcement is specified on drawings. Spandrel on beam is reinforced, with a bar that goes into the bent section of beam re-bar. Substantial spans of 10 m were achieved over the store space with a beam 1.30 deep. Balconies as projections are bonded to the structure.

The Flats for the engineer Papaleonardou in 1925 [33], by the architect K. Kitsikis show a heavily eclectic design characterised by very long projecting balconies and cornice, bonded in the concrete structure (Fig. 5). The construction shows the need to fill the lower walls with masonry as the building proceeds to the upper floors, done for the convenience to hold the scaffolding for the upper floors and to speed up fitting out, as stonework was being prepared at the earlier stages for the ground floor cladding. Similar characteristics in the construction are shown in the neighbouring Korkodeilos mansion, later in 1934.



Figure 5. The Papaleonardou Flats under construction [33]

The Polyklinikí building (1934-38 on the contract) follows a rather austere classical architectural scheme, as neoclassicism was going out of fashion by that time. Figure 6 shows the frame complete but without infill walls to increase seismic and shear strength. The Hennebique system's typical chamfered junctions of the columns of the frame can still be observed in the exterior and especially the area where deeper beams are used, dissimilar in size from the columns, probably where higher changes in shear were expected due to stiffness. Most spans longitudinally are regular and small (less than 3 m). The deep beam is probably required for a relatively larger span and more careful examination of the photo shows the entire bay with this span within the building to follow this type of junction. Infill brickwork actually wraps around the skeleton to create what appears to be a stair shaft – it should be noted that this usually stiff core is not located at the centre of the building, just one corner, following probably an architectural rather than structural demand. A deep parapet crowns the building, apparently in concrete, and may have been conceived as a bracing finish to bind together the upper part of the building, mostly against earthquakes. In general, compaction of concrete seems good.



Figure 6. The skeleton of the Polikliniki Building (1934-38) [34]

Their most structurally ambitious building though was the Hippodrome of Athens in 1924, a project to regenerate a marshland area in Faliro, which created a cantilevering canopy over the stands, though not a true shell as Torroja's Zarzuela Hippodrome in Spain later.



Figure 7. The canopy of the Hippodrome of Athens, 1924 [35]

Discussion

This short technical commentary of the work of Andreas Dracopoulos through the Ergoliptiki company, based on G. Lambrou's monograph, showed their role in establishing concrete quickly as a mainstream material in early twentieth century Greece, building a very wide client basis and body of works, of variable scale (from private villas to large public works). No major problems have been reported on the structure of their buildings so the good preservation state can be considered as a testimony to Dracopoulos's skills and the company's ability to learn quickly a brand new construction system. The overview showed they became successful agents of the Hennebique system, without the need to import specialists as was the practice abroad, so it would be interesting to further scrutinise their projects, through the documentation or in situ (Majestic Hotel, Papaleonardou Flats) to verify the extent of innovation or even appropriation and adaptation they applied to the system. This could inform how far Dracopoulos became a technology pioneer, as well as a major professional contractor, exactly in the post-1919 period when contracting as business culture was being established across Europe.

The projects overview shows constant use of the Hennebique system through the major period of Ergoliptiki, up to Greece's surrender in war in 1941 and, together with other reasons, their practice almost followed the system's demise in Greece. It would be worthy to investigate the extent of the Hennebique monopoly in the profession in Greece and whether the generation of codes in 1954 was a reaction to it or an attempt to regulate a too wide stream of unpatented applications that may have appeared, if the Hennebique agents had not had a strong hold in Greece, as it appears.

The bibliographic research showed that the status of Dracopoulos and Ergoliptiki have not been recognised among the other better known figures [36] and other agents like M Diamantopoulos or even the builders of the emblematic Giannarou Mansion need to be equally known. Equally important, stronger parallels should be made with the development of cement production and the very successful industry in Greece (Titan, AGET Iraklis). This study has hopefully added more reasons for deeper research into these fields in Greece and stronger context, which deserves to be framed in a wider Engineering heritage profile like those published for England [37] or Italy [38].

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